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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : C08L 95/00, B09B 3/00, E01C 7/18, C08K 11/00

A1

(11) International Publication Number: WO 98/18864

(43) International Publication Date: 7 May 1998 (07.05.98)

(21) International Application Number: PCT/GB97/02968

(22) International Filing Date: 28 October 1997 (28.10.97)

(30) Priority Data:
9622355.7 28 October 1996 (28.10.96) GB

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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: PROCESS FOR REMOVING OF DOMESTIC WASTE INCINERATOR RESIDUE

(57) Abstract

A process is provided for the remediation of bottom ash from domestic waste incinerators which comprises hot mixing from 10 to 50 % by weight of said bottom ash with from 4 to 6 % by weight of bitumen having a penetration of from 50 to 200 pen, from 25 to 55 % by weight of crushed rock having a particle size greater than 2 mm, from 10 to 35 % by weight of crushed rock fines having a particle size of less than 2 mm and from 0 to 3 % by weight of a filler to give a hot mix asphalt product which is environmentally stable and which has load bearing properties at least as good as conventional hot mix asphalts.

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PROCESS FOR REMOVING OF DOMESTIC WASTE INCINERATOR RESIDUE

The present invention relates to a method for the remediation of bottom ash from domestic waste incinerators and the production of an asphalt which is suitable for use in the construction of roads.

The ever-increasing volume of domestic waste has resulted in a considerable pressure on available landfill space. One process that has been developed to reduce this pressure is the incineration of the waste in high-temperature incinerators at combined heat and power facilities. In this process, domestic waste is incinerated at temperatures of 1000°C or more, producing electricity, steam, fly ash and bottom ash (the latter is also known as domestic waste incinerator residue - D.I.R.). The bottom ash and fly ash differ both in particle size and chemical composition. Some metals can be retrieved from this bottom ash (e.g. by electromagnetic and eddy current separation), but this still leaves a mass of material which until now has had no use and was simply disposed of in landfill sites. Even this disposal causes problems, because of high metal concentrations in leachate produced from the bottom ash. In particular, the levels of lead, copper, zinc and chromium are greater than the relevant environmental guidelines (drinking water and groundwater guidelines).

It would be highly desirable, therefore, to develop a process for the remediation of bottom ash from domestic waste incinerators to give a material whose leachate was more environmentally stable. Furthermore, it would be desirable for the remediation process to give a material with useful properties rather than simply disposing of it in landfill sites.

Asphalt stabilisation is a remediation technology that has been developed and applied for some considerable time. The process is designed to bind contaminated material in a stable product, reducing risks associated with dermal contact, ingestion and leaching of contaminants to groundwater and surface water. In addition, the process eliminates the need for landfill disposal of contaminated material and associated environmental problems that may arise.

Currently, technology of this type is used to recycle road plannings, reducing the demand for virgin aggregates and recycling the old road surface material. Two methods are used to process materials, hot mix bituminous concrete production and the cold mix method. In these processes an asphalt binder is mixed with soil/stone aggregate and blended to ensure each soil grain and stone aggregate is coated with a thin layer of asphalt. In order to mix the asphalt binder, which is a solid at room temperature, with the aggregate it must be in a liquefied form. Hot mix bituminous concrete production uses heat to liquefy the solid asphalt. The cold mix process, also known as Asphalt Emulsion Stabilisation (AES), uses a mixture of water and surfactants to get asphalt into a workable liquid form.

Asphalt stabilisation has not, however, previously been successfully applied to the remediation of bottom ash from domestic waste incinerators. It is an object of the present invention to provide a process of remediating bottom ash from domestic waste incinerators using asphalt stabilisation technology. It is a further object of the invention to provide a remediated product which is both environmentally stable and suitable for use in the construction of roads.

Thus, in a first aspect of the present invention there is provided a process for the remediation of bottom ash from domestic waste incinerators comprising hot mixing from 10 to 50% by weight of said bottom ash with from 4 to 6% by weight of bitumen having a penetration of from 50 to 200 pen, from 25 to 55% by weight of crushed rock having a particle size greater than 2 mm, from 10 to 35% by weight of crushed rock

fines having a particle size less than 2 mm and from 0 to 3% by weight of a filler to give a hot mix asphalt product.

This process remediates the bottom ash to give an asphalt product which is more environmentally stable, particularly with regard to leachate levels of metals such as lead, copper and zinc, and which has similar properties to conventional hot mix asphalts obtained from virgin aggregate, making it suitable for use in the construction of roads.

In a further aspect of the present invention, there is provided a hot mix asphalt comprising from 10 to 50% by weight of bottom ash from a domestic waste incinerator, from 4 to 6% by weight of bitumen having a penetration of from 50 to 200 pen, from 25 to 55% by weight of crushed rock having a particle size of greater than 2 mm, from 10 to 35% by weight of crushed rock fines having a particle size of less than 2 mm and from 0 to 3% by weight of a filler.

The bitumen used in the present invention has a penetration of from 50 to 200 pen, as determined according to British Standard Specification (B.S.) 3690 (a test which is based on viscosity ranking test; 1 pen = 0.1 mm). Preferably, from 4.7 to 5.5% by weight of bitumen is added to the hot mix.

The crushed rock used in the present invention is the coarse aggregate element and refers to the particles whose size exceeds 2 mm, as tested using the appropriate British Standard test sieve. It is obtained from the quarry process of blasting, crushing and screening of a mineral deposit. The crushed rock used can be any conventionally used in the production of hot mix asphalts e.g. limestone and granite. Preferably, from 29 to 52% by weight of crushed rock is added to the hot mix.

The crushed rock fines are particles whose size is less than 2 mm, as tested by the appropriate B.S. test sieve, and are obtained from the same quarry process on the crushed rock. Preferably, from 12.5 to 32% by weight of crushed rock fines are added to the hot mix.

The fillers used are those conventionally used in the production of hot mix asphalts. They are generally powders whose particle size is substantially less than 75μm as tested by the appropriate British Standard test sieve. Examples of suitable fillers include the product of milling limestone aggregate. Preferably 2% by weight of filler is added.

In a preferred embodiment of the present invention, the bottom ash is subjected to electromagnetic and eddy current separation before the mixing process to remove substantially all of the ferrous metal and up to 60% of the non-ferrous metal. The bottom ash can also, preferably, be crushed and screened to reduce the average particle size before the mixing process.

The precise amounts of the different components can be varied according to the intended use for the asphalt product. Thus, for example, surface course material which complies with the requirements of 10 mm wearing coarse British Standard 4987 (in terms of gradation, binder content and temperature for mix and lay) is obtained by hot mixing the following components according to the process of the present invention.

Raw Materials	**% Composition**		
Domestic Waste Incinerator Residue	10	20	50
Bitumen 50 pen, 100 pen, 200 pen	5.5	5.5	5.5
Crushed Rock	52	46	30
Crushed Rock fines	30.5	26.5	12.5
Limestone Filler	2	2	2

Basecourse asphalt which complies with the requirements of a 20 mm dense basecourse macadam British Standard 4987 (in terms of gradation, binder content and temperature of mix and lay) is obtained by hot mixing the following components according to the present invention.

Raw Materials	% Composition		
	Mix A	Mix B	Mix C
Domestic Waste Incinerator Residue	10	20	50
50 Pen Bitumen	5	5	5
Screened Crushed Rock	51	45	20
Crushed Rock Fines	32	28	14
Limestone Filler	2	2	2

The present invention can be further understood by consideration of the following examples, in which the reduction in leachate metal concentrations and the loading bearing properties of the hot mix asphalt of the present invention were tested.

Using a hot mix asphalt plant, the following materials were combined according to the present invention to give an asphalt which met the requirements of British Standard 4987 as a basecourse macadam.

Component	Source	% by weight
Coarse Aggregate	Bardon Hill Quarry Hardstone aggregate	28.3
Fine Aggregate	Bardon Hill Quarry Hardstone aggregate	15.0
D.I.R.	South East London Combined Heat and Power, Deptford	50.0
100 Pen Bitumen	B.P. Bitumen Llandarcy	4.7
Limestone Filler	Francis Flowers, Somerset	2.0

The concentration of various metals in the leachates from the bottom ash (D.I.R.) were compared with those obtained from hot mix product containing 100% virgin aggregate (i.e. no bottom ash) and those obtained from the test hot mix asphalt prepared as stated above. The three samples were prepared for National Rivers Authority (UK) Leaching Tests (NRA, 1994). The bottom ash sample and the two processed materials were crushed with a jaw crusher to produce a particle size of less than 5 mm. A sample of bottom ash was subdivided out for total metal analyses. The

crushed samples were then coned and quartered to produce four samples for leach tests. All four sub-samples of each material were processed according to the NRA procedure. Leachate "blank" samples with no added material were also run through the procedure for quality control analyses.

Bottom ash (solid) samples and all leachate samples were anlaysed for the following metals:

- Silver (Ag)
- Arsenic (As)
- Boron (B)
- Cadmium (Cd)
- Cobalt (Co)
- Chromium (Cr)
- Copper (Cu)
- Mercury (Hg)
- Molybdenum (Mo)
- Nickel (Ni)
- Lead (Pb)
- Antimony (Sb)
- Selenium (Se)
- Tin (Sn)
- Tellurium (Te)
- Thallium (Tl)
- Zinc (Zn)

The results of the analyses are presented in the following Tables 1 through 6. Total metal concentrations in bottom ash were measured in duplicate and are documented in Table 1 with average concentrations shown in Table 2. Levels of lead and chromium in the ash were greater than ICRCL guidelines (ICRCL, 59/83, 2nd Edition, July 1987), commonly used to gauge the significance of soil contamination at development sites.

Metal concentrations in leachates from bottom ash, hot mix and hot mix product with added ash are shown in Tables 3, 4 and 5 respectively. The average concentration in the four leachates from each material were calculated. As seen in Table 6, the concentration of several metals including copper (Cu), lead (Pb) and zinc (Zn) were above available environmental standards in the bottom ash leachate. The concentrations in leachate were compared to Dutch groundwater guidelines and the EU drinking water directive (Council of the European Communities, 80/778 EEC:OJL 229, 30 August 1980) that forms the basis for UK drinking water standards. It is important to note that leach test conditions including the small particle size required to conduct the leach test may over estimate any actual concentrations that may arise in the environment due to natural leaching of this material.

Table 6 also includes the calculated percent reduction in leachate metal concentrations comparing bottom ash leachate and hot mix product with incorporated bottom ash. Generally, the higher concentration metal species in the bottom ash leachate showed the greatest percent reduction in the hot mix product.

Figure 1 shows the relative concentrations for bottom ash leachate, hot mix leachate and hot mix with ash leachate. The concentrations are plotted on a log scale due to the large range of concentrations in the leachates. Where metals were below detection limits, the plots in Figure 1 indicate a concentration set at half the detection limit. Lead, copper and zinc were above relevant environmental guidelines in the bottom ash leachate and were reduced in the hot mix product between 93 and 98 percent. All three metals were below the environmental guidelines in the hot mix with ash product leachate. Metals present in the bottom ash leachate at low concentration have similar levels in the hot mix with ash product. Only a few metals were found in the basic hot mix (no added ash) leachate at low concentration.

Overall the percent reduction in leachate metals concentrations indicates the hot mix processing of incinerator bottom ash produces an environmentally more stable material, binding metals in a form that restricts environmental leaching of metal

contaminants. The leaching test represents conditions more favourable to leaching than would be expected for hot mix production in its proposed use.

The product can be used for paving roads forming a low permeability material compacted during road surfacing. In the leaching test the material was crushed into a finely divided state with a particle size less than 5 mm, thus creating a much larger surface area than would be the case for the paving material in common use. In addition, significant dilution of any leachate generated from the pavement would further reduce any concentration in the environment.

Table 1 Bottom ash total metals

Species	Detection Limit	Test 1	Test 2
	(mg/kg)	(mg/kg)	(mg/kg)
Ag	0.02	0.74	0.49
As	2	6	8
B	1	94	74
Ba	0.1	460	480
Be	0.02	0.57	0.47
Cd	0.2	3.7	2.8
Co	0.3	15	13
Cr	0.3	79	140
Cu	0.3	1500	930
Hg	1	ND	ND
Mo	0.1	14	13
Ni	0.3	66	250
Pb	0.5	1600	1300
Sb	0.1	34	28
Se	9	ND	ND
Sn	0.3	93	80
Te	3	ND	4
Ti	0.2	1600	1300
Tl	0.4	1	6.8
Zn	0.2	1200	930

ND (Not Detected)

Table 2 Average metal concentration in bottom ash

Species	Detection Limit	Test 1	Test 2	Average Concentration
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Ag	0.02	0.74	0.49	0.615
As	2	6	8	7
B	1	94	74	84
Ba	0.1	460	480	470
Be	0 02	0.57	0.47	0.52
Cd	0.2	3.7	2.8	3.25
Co	0.3	15	13	14
Cr	0.3	79	140	109.5
Cu	0.3	1500	930	1215
Hg	1	0 5	0 5	0.5
Mo	0.1	14	13	13.5
Ni	0 3	66	250	158
Pb	0 5	1600	1300	1450
Sb	0.1	34	28	31
Se	9	4.5	4.5	4.5
Sn	0.3	93	80	86.5
Te	3	1.5	4	2.75
Ti	0.2	1600	1300	1450
Tl	0.4	1	6.8	3.9
Zn	0 2	1200	930	1065

Non - detected species set at 0.5 Detection Limit

Table 3 Metals concentrations in bottom ash leachates

Species	Detection Limit	Blank	Bottom Ash Leachate Test 1	Bottom Ash Leachate Test 2	Bottom Ash Leachate Test 3	Bottom Ash Leachate Test 4
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Ag	0.01	ND	ND	ND	ND	ND
As	0.0006	ND	0.001	ND	ND	ND
B	0.04	ND	ND	ND	ND	ND
Ba	0.004	ND	0.46	0.44	0.39	0.41
Be	0.0007	ND	ND	ND	ND	ND
Cd	0 00005	ND	0.0001	0.0004	0.0002	0.0003
Co	0.009	ND	ND	ND	ND	ND
Cr	0.01	ND	ND	ND	ND	ND
Cu	0.009	ND	1.4	1.3	1.3	1.4
Hg	0.0004	ND	ND	ND	ND	ND
Mo	0.004	ND	0.047	0.044	0.044	0.046
Ni	0.01	ND	ND	ND	ND	ND
Pb	0.0002	ND	0.38	0.29	0.26	0.27
Sb	0.00004	ND	0.0039	0.0045	0.0044	0.0042
Se	0.003	ND	0.035	0.02	0.035	0.037
Sn	0.0001	0.0005	0.0012	0.0015	0.0014	0.0015
Te	0.0009	ND	ND	ND	ND	ND
Ti	0.007	ND	ND	ND	ND	ND
Tl	0.0001	ND	ND	0.0016	0.0014	ND
Zn	0.006	0.008	0.13	0.13	0.094	0.095

Table 4 Metal concentrations in hot mix leachate

Species	Detection Limit	Blank	Hot Mix Leachate Test 1	Hot Mix Leachate Test 2	Hot Mix Leachate Test 3	Hot Mix Leachate Test 4
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Ag	0.01	ND	ND	ND	ND	ND
As	0.0006	ND	ND	0.002	ND	ND
B	0.04	ND	ND	ND	0.04	ND
Ba	0.004	ND	0.03	0.02	0.02	0.02
Be	0.0007	ND	ND	ND	ND	ND
Cd	0.00005	ND	ND	ND	ND	ND
Co	0.009	ND	ND	ND	ND	ND
Cr	0.01	ND	ND	ND	ND	ND
Cu	0.009	ND	ND	ND	ND	ND
Hg	0.0004	ND	ND	ND	ND	ND
Mo	0.004	ND	ND	ND	ND	ND
Ni	0.01	ND	ND	ND	ND	ND
Pb	0.0002	ND	ND	ND	ND	ND
Sb	0.00004	ND	0.00053	0.00042	0.0003	0.0004
Se	0.003	ND	0.008	0.008	0.005	0.005
Sn	0.0001	0.0005	0.0004	0.0005	0.0003	0.0004
Te	0.0009	ND	ND	ND	ND	ND
Ti	0.007	ND	ND	ND	ND	ND
Tl	0.0001	ND	ND	0.0003	ND	ND
Zn	0.006	0.008	0.02	ND	0.007	ND

Table 5 Metal concentrations in hot mix with bottom ash leachate

Species	Detection Limit	Blank	Hot Mix w/bottom ash Leachate Test 1	Hot Mix w/bottom ash Leachate Test 2	Hot Mix w/bottom ash Leachate Test 3	Hot Mix w/bottom ash Leachate Test 4
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Ag	0.01	ND	ND	ND	ND	ND
As	0.0006	ND	0.002	0.001	ND	ND
B	0.04	ND	ND	ND	ND	ND
Ba	0.004	ND	0.051	0.048	0.049	0.057
Be	0.0007	ND	ND	ND	ND	ND
Cd	0.00005	ND	0.00007	0.00009	ND	ND
Co	0.009	ND	ND	ND	ND	ND
Cr	0.01	ND	ND	ND	ND	ND
Cu	0.009	ND	0.03	0.02	0.02	0.03
Hg	0.0004	ND	ND	ND	ND	ND
Mo	0.004	ND	0.01	0.009	0.01	0.01
Ni	0.01	ND	ND	ND	ND	ND
Pb	0.0002	ND	0.0086	0.008	0.0082	0.0096
Sb	0.00004	ND	0.018	0.018	0.019	0.02
Se	0.003	ND	0.052	0.046	0.041	0.047
Sn	0.0001	0.0005	0.001	0.0011	0.001	0.0011
Te	0.0009	ND	ND	ND	ND	ND
Ti	0.007	ND	ND	ND	ND	ND
Tl	0.0001	ND	ND	ND	ND	ND
Zn	0.006	0.008	ND	0.01	0.01	0.01

Table 6 Percent reduction in leachate concentration and environmental standards

Species	Bottom Ash Leachate (average)	Hot Mix Leachate (average)	Hot Mix w/ Bottom Ash Leachate (average)	% Reduction comparing Bottom Ash Leachate with Hot Mix w/ Bottom Ash Leachate	Dutch IV	EEC MAC
	(mg/l)	(mg/l)	(mg/l)		(mg/l)	(mg/l)
Ag	0.005	0.005	0.005	0		0.01
As	0.000475	0.000725	0.0009	-89		0.05
B	0.02	0.025	0.02	0		
Ba	0.425	0.0225	0.05125	88	0.625	
Be	0.00035	0.00035	0.00035	0		
Cd	0.00025	0.000025	0.0000525	79		0.005
Co	0.0045	0.0045	0.0045	0	0.1	
Cr	0.005	0.005	0.005	0		0.05
Cu	1.35	0.0045	0.025	98	0.075	
Hg	0.0002	0.0002	0.0002	0		0.001
Mo	0.04525	0.002	0.00975	78	0.3	
Ni	0.005	0.005	0.005	0		0.05
Pb	0.3	0.0001	0.0086	97		0.05
Sb	0.00425	0.0004125	0.01875	-341		0.01
Se	0.03175	0.0065	0.0465	-46		0.01
Sn	0.0014	0.0004	0.00105	25		
Te	0.00045	0.00045	0.00045	0		
Ti	0.0035	0.0035	0.0035	0		
Tl	0.000775	0.0001125	0.00005	94		
Zn	0.11225	0.00825	0.00825	93	0.065	

Negative % reduction indicates higher concentration in treated material (only found where original ash contained very low concentrations

(Dutch IV) Dutch groundwater guideline intervention value

(EEC MAC) EU drinking water directive maximum admissible concentration

To evaluate its potential as a roadstone for use in the construction of highways, the load bearing properties of the test asphalt of the present invention were determined by measuring its elastic siffness using a Nottingham Asphalt Tester. In all tests performed on the asphalt of the present invention, the load bearing properties were found to be at least as good as conventional hot mix asphalt.

Through careful adjustment of the amounts of the various components combined in the hot mixing process of the present invention, it is possible to obtain asphalts which are suitable for use as basecourses and surface courses in the manufacture of highways.

CLAIMS:

1. A process for remediation of bottom ash from domestic waste incinerators comprising hot mixing from 10 to 50% by weight of said bottom ash with from 4 to 6% by weight of bitumen having a penetration of from 50 to 200 pen, from 25 to 55% by weight of crushed rock having a particle size greater than 2 mm, from 10 to 35% by weight of crushed rock fines having a particles size of less than 2 mm, and from 0 to 3% by weight of a filler to give a hot mix asphalt product.

2. A process according to claim 1, wherein 4.7 to 5.5% by weight of bitumen is present in the hot mix composition.

3. A process according to claim 1 or claim 2, wherein from 29 to 52% by weight of crushed rock having a particle size greater than 2 mm is present in the hot mix composition.

4. A process according to any one of claims 1 to 3, wherein from 12.5 to 32% by weight of crushed rock fines is present in the hot mix composition.

5. A process according to any one of claims 1 to 4, wherein 2% by weight of filler is present in the hot mix composition.

6. A process according to any one of claims 1 to 5, wherein the filler is a limestone filler having an average particle size of less than 75μm.

7. A process according to any one of claims 1 to 6, wherein the bottom ash is subjected to electromagnetic and eddy current separation before the hot mixing.

8. A process according to any one of claims 1 to 7, comprising hot mixing one of the following compositions:

(a) 10% by weight of bottom ash, 5.5% by weight of bitumen, 52% by weight of crushed rock, 30.5% by weight of crushed rock fines and 2% by weight of limestone filler;

(b) 20% by weight of bottom ash, 5.5% by weight of bitumen, 46% by weight of crushed rock, 26.5% by weight of crushed rock fines and 2% by weight of limestone filler; or

(c) 50% by weight of bottom ash, 5.5% by weight of bitumen, 30% by weight of crushed rock, 12.5% by weight of crushed rock fines and 2% by weight of limestone filler.

9. A process according to any one of claims 1 to 7, comprising hot mixing one of the following compositions:

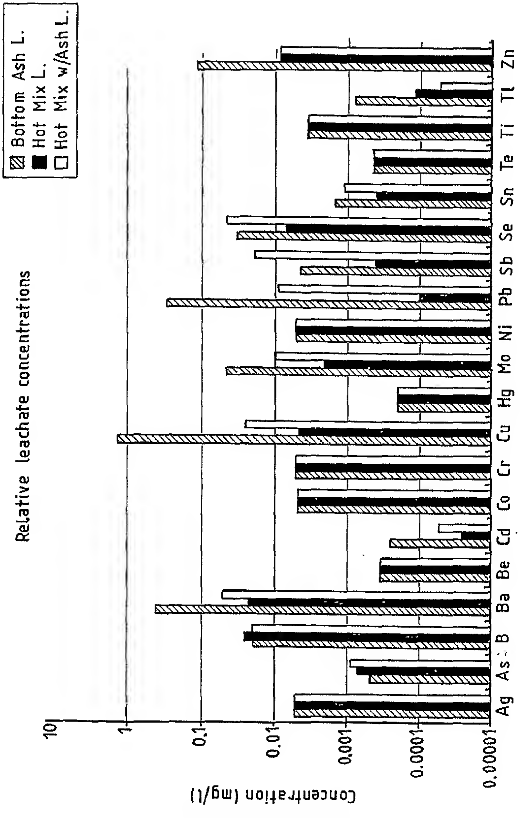
(a) 10% by weight of bottom ash, 5% by weight of bitumen, 51% by weight of crushed rock, 32% by weight of crushed rock fines and 2% by weight of limestone filler;

(b) 20% by weight of bottom ash, 5% by weight of bitumen, 45% by weight of crushed rock, 28% by weight of crushed rock fines and 2% by weight of limestone filler; or

(c) 50% by weight of bottom has, 5% by weight of bitumen, 29% by weight of crushed rock, 14% by weight of crushed rock fines and 2% by weight of limestone filler.

10. A process according to any one of claims 1 to 7, comprising hot mixing 50% by weight of bottom ash, 4.7% by weight of bitumen having a penetration of 100 pen, 28.3% by weight of crushed rock, 15.0% by weight of crushed rock fines and 2% by weight of limestone filler.

11. A hot mix asphalt obtainable according to the process of any one of claims 1 to 9.



Relative leachate concentrations
Bottom Ash L.
Hot Mix L.
Hot Mix w/Ash L.
Concentration (mg/l)
10
1
0.1
0.01
0.001
0.0001
0.00001
Ag
As
B
Ba
Be
Cd
Co
Cr
Cu
Hg
Mo
Ni
Pb
Sb
Se
Sn
Te
Ti
Tl
Zn

FIG. 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/02968

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C08L95/00 B09B3/00 E01C7/18 C08K11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C08L B09B E01C C08K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	LU 88 471 A (COOS FELIX S A R L) 2 October 1995	
A	EP 0 323 095 A (MIIKE TEKKOSHO KK) 5 July 1989	
A	FR 2 517 686 A (ZALAEGERSZEGI KOZUTIEPITO VALL) 10 June 1983	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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1

Date of the actual completion of the international search	Date of mailing of the international search report
2 February 1998	12/02/1998

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int. .tional Application No
PCT/GB 97/02968

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
LU 88471 A	02-10-95	NONE	
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